THE PROBLEM OF BREEDING FOR MILK PRODUCTION

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The problem facing the breeders of our modern dairy cattle is how to breed so that a high level of production of milk and butterfat, say, an average of 600 pounds of fat and the equivalent milk production for the various breeds, will be transmitted with as much uniformity and surety as the breeds now transmit breed characteristics.

When we mate purebred Holstein-Friesians we expect that the offspring will have the characteristics of the breed in color, size, shape, per cent butterfat, and so on. It is only rarely that we are disappointed—sometimes in color, sometimes in size, or some other feature—but usually the breed characteristics have been so fixed that they breed true. Of course there is variation within the breeds. The color of the Holstein-Friesians varies from almost all white to a predominating black; yet a purebred Holstein without some black on the body (except it be a red and white purebred), or one without some white below the knees and hocks, is almost never found. All of our breeds have their variable features, but it is not often that a Holstein-Friesian will be mistaken for a Jersey, or an Ayshire for a Brown Swiss.

All breeders are seeking to breed level top lines, broad level rumps, udders that are well balanced and well attached front and rear, teats of good size and well placed, barrels that are of good length and depth, with well-sprung ribs. These points are being fixed so that they are transmitted with considerable regularity. In some of the breeds these points in conformation seem to be transmitted with less variation than in others, indicating that these particular breeds are reaching the point where the factors controlling the conformation of the various parts of the body are pure for the desired type.

With the producing capacity, however, we do not appear to have attained the uniformity that has been secured with other breed characteristics and type. An illustration of the great variation that takes place in the producing capacity of our purebred dairy cattle may be found in the records of the tested daughters of almost any sire. Recently we studied the transmitting ability of 23 Holstein-Friesian sires that had six or more yearly-record daughters, each of which was from a dam with a yearly record. We are continuing this work with the sires of the other dairy cattle breeds. The average range in milk production between the lowest and highest producing daughters of these 23 sires was almost 9,000 pounds, while the average range in milk production of the dams of the daughters of these 23 sires was a little over 8,000 pounds. One of these sires had 20 daughters, and there was a difference of 18,000 pounds of milk between the record of his highest and his lowest producing daughter, with the production of the other daughters spread out very evenly between

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these two extremes. Between the lowest record and the highest record dam of these same daughters the spread was 19,000 pounds. There was a difference of less than 5,000 pounds of milk between the highest and lowest producing daughters of two of the sires studied. There was a spread of 4,000 pounds between the highest and lowest record daughter of one of these sires and spread of only 2,000 pounds between the lowest and highest record daughter of the other sire. Five of the seven daughters of the latter produced less than their dams. Often the producing capacity of full sisters varies greatly, a difference of 4,000 to 6,000 pounds of milk between the records of full sisters is not uncommon, and a difference as great as 10,000 pounds of milk has been noted.

An example of the uncertainty of the purebred in transmitting production occurred in the experiment of grading up from common dams of Shorthorn and Hereford ancestry, reported by the South Dakota Experiment Station. The three-grade foundation cows used had an average production of 3,759 pounds of milk and 155.9 pounds butterfat. One Holstein bull has five daughters out of these three cows and the average production of these daughters was 7,152 pounds milk and 259 pounds butterfat. This is an increase in the daughters of 100 per cent in milk and 79 per cent in butterfat. The second bull used on the daughters of the first bull got two daughters that made an average production of 10,289 pounds milk, 258 pounds butterfat. This represents an increase over their dams of 44 per cent in milk and 26 per cent in butterfat. The third bull used had only one daughter reported with a complete record. This daughter was a great-granddaughter of the original foundation cow. She was said to be of much better breed type than either her dam or grand dam, but her production was only 4,850 pounds milk and 173 pounds butterfat. This was only 150 pounds milk and 20 pounds butterfat more than was produced by her great grand dam, the foundation cow.

THE PRESENT SYSTEM OF SELECTION AS ORDINARILY PRACTICED

The present system of breeding is based on selection and may be divided into four classes. In one class are those breeders who select breeding animals by their conformation. To such breeders a bull that has won a championship at an important show is considered worthy of heading a herd of fine cows, though his pedigree or performance shows evidence of only ordinary producing ability. A cow that has ranked well up in her class in a strong show is considered a splendid foundation animal.

In the second class is the man who selects his bulls and females entirely on the strength of the records of their ancestry. Usually the greatest weight is put on the record of the dam.

In the third class is the man who selects for both type and production. This is the growing class. The animals that possess type and also have dams with good records are the animals that command the best prices in the sales ring.

In the fourth class, which may be, and usually is, a part of one of the above methods of selection, is the breeder who believes emphatically that he must stick to a single family in his selection of breeding animals. He believes that either line breeding or inbreeding is necessary in order to get desirable results.

There is, of course, the breeder who does not believe in mating related animals.

Are any or all of these methods of selection accomplishing the purpose of helping us fix the tendency for high milk-producing capacity in our dairy breeds, so that our young bulls may be expected to transmit high milk and butterfat-producing capacity with the same certainty that we expect them to transmit their breed characteristics? If not, why are they failing?

SELECTION BY TYPE

It may be questioned whether we really know the fundamental relationship between the conformation of certain parts of the body and the functions of the body. For years dairy husbandry students have been taught in our agricultural colleges that a large heart girth in a cow means a large heart and lungs and that large heart and lungs indicate a superior constitution; that a large barrel means a large capacity for handling feed; that well-developed milk veins mean a large flow of blood to the udder, and so on. Do we really have facts on which to base these teachings? Does a large heart girth really indicate a large heart and lungs; and if so, do large heart and lungs really mean that the dairy cow having them is more capable of heavy production of milk and butterfat than a cow with much smaller heart and lungs? Also does large stomach and intestinal capacity mean greater ability to digest and assimilate large amounts of feed? The Bureau of Dairy Industry is working on this problem, trying to determine the correlation between the outward measurements of the body and the size of the corresponding organs; and then the fundamental problem whether there is a relationship between the size of the vital organs and the producing capacity of the animals. It has already been demonstrated that animals with small milk veins and wells do not necessarily have a limited flow of blood to the udder, and that a part of the flow may be taken care of in the interior veins that are not visible outwardly. Even if it is found that there is a relationship between conformation and producing capacity, a favorable conformation will only indicate that it will be possible for a certain animal to produce well, provided that animal has the inheritance that will stimulate large production. Since we know that inheritance governing all characteristics is transmitted through the germ plasm, it does not seem possible that we will ever be able to tell by the appearance of an animal what its inheritance for production is. But it does seem possible that we may be able to determine the limitations of an animal to produce by its conformation. For example, if it is found that a large heart girth is correlated with a large heart and lungs, and that a large heart and lungs are essential for heavy production, and an animal is found with a small heart girth, its producing capacity will be limited regardless of how good an inheritance for great production it may possess. These things may indicate the limitations of an animal to make full use of an inheritance of great production, but it seems improbable that they will ever indicate to us whether the animal has such an inheritance. It does not seem possible to breed cattle that will be pure for the factors governing high production, by selection based on type alone.

SELECTION ON THE BASIS OF PRODUCTION RECORDS

Selection on the basis of production records of dams is leading to a gradual improvement in the producing capacity of our purebred dairy cattle, but it is by no means a sure method of improvement. The producing capacity of our dairy cattle will be subject to great variation for years to come if we use only this method of selection. When a cow shows great producing capacity we must assume that she has at least a part of the factors in her germinal make-up that go to determine the ability for large production, otherwise she would not be a large producer. When we see a polled cow, however, we can not be certain that she does not have in her germ plasm the factors that will cause the growth of horns. And so with a cow of great producing capacity, we can not be certain that she does not have in her germ plasm the factors that will cause low production. Then, too, the germinal make-up of the offspring of this high-producing cow will depend partly on the sire she is mated with. If the function of high production is a dominant character, as it appears to be, then it will be a difficult matter by basing selection on the production records of the dam to breed a strain that will be pure for high production.

SELECTION ON THE BASIS OF PRODUCTION RECORDS AND CONFORMATION

When the actual relation between outward conformation of the body and the corresponding organs is definitely known, and when the relationship of the size or development of certain organs and the producing capacity of the cow is known, and if these relationships are positive, then our knowledge of conformation will assist us in eliminating the animals that have a weakness that would inhibit the full development of an inheritance for great producing capacity. Such knowledge would save considerable time and effort by eliminating the use of animals that can not be of benefit in the breeding program. On the other hand, many animals are discarded because of poor individuality, though they have an inheritance for high-producing capacity that would be of material benefit in building strains that would be pure for high production. Naturally, there are many more animals that are good for either production alone or type alone than there are that have both great producing capacity and the desired type. The field of animals to be selected from, for building strains that are pure for high production, and at the same time have the factors for good type, is therefore limited.

THE PRACTICE OF MATING RELATED ANIMALS

Breeders generally have been taught to believe that the most uniform results in breeding work will be secured by mating related animals, and especially that greater uniformity in type will be secured by this practice. But, in fact, if the same general type has been fixed in two unrelated families there is no reason why the crossing of these two unrelated families should result in offspring having a great variation in type. Where families of distinctly different types are mated, a variation in type in the offspring is to be expected.

The theory that it is necessary to mate related animals, or to breed within a family, if desirable results are to be secured, has developed among our breeders to the point where it is almost a fetish. This belief is the result of both teaching and commercial practice. The fact that most of the early breeders of the English breeds practiced very close breeding in order to fix the characters they sought has been a primary reason for the practice being recommended and taught in our colleges. Probably those early English breeders had but few desirable breeding animals from which to select, and when they did find animals with the characters they wanted they had to inbreed to fix these characters because unrelated animals carrying these characters were not available. Breeders of plants and laboratory animals have also found that any certain characteristic could be fixed by close breeding.

Commercial practices have entered into the establishment of this theory. A breeder makes a reputation on a certain family, or strain, which he has developed. This family is advertised. Soon a group of breeders are developing and advertising this family. If the breeder who buys a bull of this family believes it is necessary to make related matings, his next bull will be purchased from the same breeder or will at least carry the same blood lines. The herd of some breeder, who has made a reputation with a certain family, may be in need of improvement that could be brought about by an outcross to another family, but the breeder will not make this outcross because he fears that to do so would mean acknowledging to the public the superiority of the other family, thereby weakening the prestige of his own family. Very often the extensive advertising of a family and the backing of that family by influential people have caused it to gain such popularity that it commands higher prices than others that have greater merit. In one of our dairy breeds one family has gained such widespread popularity that animals not having a top cross of this family can not command high prices. Commercialism has led to the breeding of distinct strains of families within breeds, and to the widespread expansion of the theory of line breeding. It has limited the selection of breeding animals to the family in which the breeder is interested. New strains have been developed with the power of great improvement, but they have died out because of inability to market the animals as a result of this aversion of breeders to mating outside their established families.

In a study of the transmitting ability of 87 Guernsey sires that were ranked both according to the average production of their daughters and according to the average increase in production of the daughters over their dams, 16 were classed as inbred, 24 were classed as line bred, and 47 were classed as outbred. Dividing these 87 sires into three groups of 29 each, the best, medium, and poorest sires, it is found that 31 per cent of the inbred sires are in the best group, 44 per cent in the medium group, and 25 per cent are in the poorest group, 46 per cent of the line bred sires are in the best group, 25 per cent in the medium group, and 29 per cent are in the poorest group; 28 per cent of the outbred sires are in the best group, 34 per cent in the medium group, and 38 per cent in the poorest group. While the greatest percentage of the line-bred sires are in the best group and the greatest percentage of the inbred sires are in the medium group, the distribution of inbred, line-bred, and outbred sires among the three

groups is so even as to indicate that close breeding is not necessary in order to secure prepotency in sires. It would seem to be as possible for the outbred sire to be homozygous for the factors determining high-producing capacity, if he is the result of a fortunate mating, as it is for the inbred sire.

An interesting illustration of the effect of the different forms of mating on production ability is to be had in the daughters of three sires, father, son, and grandson, respectively, each of which had some inbred, some line-bred, and some outbred daughters. Sire A, outbred, had 2 inbred, 4 line-bred, and 11 outbred daughters. The two inbred daughters had an average production of 756 pounds butterfat; the 4 line-bred daughters an average of 581 pounds butterfat; the 11 outbred daughters an average of 605 pounds butterfat. The inbred daughters had an average increase over their dams of 63 pounds butterfat; the line-bred daughters had an average increase of 56 pounds, and the outbred daughters an average increase of 101 pounds.

Sire B, an inbred son of sire A, has 4 inbred, 7 line-bred, and 8 outbred daughters. The inbred daughters average 690 pounds butterfat; the line-bred daughters average 762 pounds butterfat; and the outbred daughters average 675 pounds butterfat. The inbred daughters have an average increase over their dams of 29 pounds, the line-bred daughters an average increase of 193 pounds, and the outbred daughters an average increase of 56 pounds butterfat.

Sire C is a son of sire B. He is classed as line bred. He has 4 inbred daughters, 1 line-bred, and 2 outbred. His inbred daughters average 684 pounds butterfat, his line-bred daughter has a record of 406 pounds butterfat; and his outbred daughters an average of 720 pounds butterfat. The inbred daughters show an average increase of 17 pounds butterfat over their dams, the line-bred daughters an average increase of 27 pounds, and the outbred daughters show an average increase of 171 pounds butterfat.

Here are three closely related sires of unusual merit, all securing excellent producing daughters in the different degrees of closeness of mating, but each one having his highest producing daughters in a different class; that is, sire A's highest producing daughters are inbred, sire B's highest producing daughters are line-bred, and sire C's highest producing daughters are outbred. Sire B's line-bred daughters had the greatest average increase over their dams, while the outbred daughters of both A and C showed the greatest average increase. It is apparent that a daughter or son may be homozygous for the factors determining high milk and butterfat producing capacity without its sire and dam being related.

WHAT KIND OF MATINGS SHOULD BE MADE?

In order to breed animals that will have uniformly high-production ability, animals must be mated which possess only those hereditary factors that will determine high-production capacity; or at least one of the parents must possess all hereditary factors determining high-producing capacity, and they must be dominant over the factors that determine low production. In other words, in order for the F generation to be uniformly high producers either both parents must be pure for those hereditary factors that will determine high production or else one parent must be homozygous for

dominant hereditary factors determining high production. The latter type of mating may get animals that will be uniformly good producers, but unless these offspring are homozygous for the hereditary factors that determine high-producing capacity they will not breed true unless the animals to which they are mated are homozygous for dominant factors determining high production. Why inbreed? Why line breed? If sire A is homozygous for dominant factors determining high production and his heterozygous daughters are bred back to him, half of his inbred offspring will be homozygous and half heterozygous. What will be the result if sire A's daughters are mated to sire B, who is also homozygous for dominant factors determining high-producing capacity, but is not related to sire A? If sire B has the same combination of factors that enables him to sire high-producing daughters as has sire A, there is no reason why the result should not be the same as when sire A's daughters are mated back to him. In either case the percentage of offspring that are homozygous for these factors determining high production will be greatly increased. But it is not yet certain that sire A and sire B, representing different families or strains of the same breed, and both having proven by the producing ability of their get that they are homozygous for the factors determining high production, have the same factors or combination of factors that enables each of them to get the same desirable results. The indications from studies of advanced registry records are that the factors controlling high-producing capacity are alike in most highly prepotent sires of the same breed.

The advantage of inbreeding or line breeding in fixing high production is the reappearance, in the pedigree of the sire or dam definitely known to be a great breeder. Ancestors that might be poor are eliminated to the extent of the duplication, and thereby the chances of the individual receiving the desired hereditary factors from the great breeding ancestor are correspondingly increased. Should more complete evidence show that unrelated prepotent sires of the same breed gain their prepotency through different hereditary factors, or different combinations of hereditary factors, then it may be necessary to mate closely related animals in order that the offspring receive the same combination through both parents. If, however, the evidence continues to point to the unrelated sires of a breed that are proving great breeders, all deriving their prepotency from the same grouping of hereditary factors, then the breeding of cattle that will be homozygous for the factors controlling high producing capacity is going to be accomplished most rapidly by the continuous use of sires, within a breed, related or unrelated, that have proven by the uniformly high production of their daughters that they are homozygous for the factors controlling high-producing capacity.

Still another method of breeding is suggested by the results of Wright's guinea-pig experiments and Jones's experiments with corn. In the inbreeding experiments with guinea pigs Wright has found that in most of the families used a decline in all the elements of vigor, as weight, fertility, and vitality, resulted from inbreeding. When these inbred families were crossed, however, there was an improvement over both parental stocks in all elements of vigor. Jones has secured similar results in crossing inbred strains of corn.

By crossing our inbred families of dairy cattle within breeds, of course, we may expect to secure cattle with greater vigor, and through the new combinations of the more dominant factors for the desired characters of the families crossed, some animals will be superior to either of the parent families. These superior animals may form the foundation herd from which new inbred families may be developed and crossed.

In the Bureau of Dairy Industry's breeding experiments with dairy cattle, the effects of both inbreeding and outbreeding with the same sires will be compared. The attempt to breed a line that will be pure for high production is being made by using for generation after generation only such sires as have proven their ability to transmit uniformly high production. All the bulls born in the breeding herds are being proved by loaning them to farmers who keep production records of the heifers these bulls sire. There are now over 65 bulls loaned that are being proved. Those that show indications of being homozygous for the factors controlling high production and good type will be used in the experiments.

The two most important problems in breeding animals that will be pure for high production are, first, to determine whether it is the same grouping of hereditary factors in each of the prepotent sires within a breed that enables them to transmit uniformly high production to their get, and, therefore, whether the use of these unrelated sires regardless of relationship will tend to build a strain that will be pure for the factors determining high production, and, second, if it is discovered that these prepotent sires of a breed all have the same hereditary factors controlling production, to find enough homozygous sires for these hereditary factors to enable us in the course of a few generations of breeding to produce a strain that will be pure for high production.

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